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Quantification of Within-Plant and Within-Field Yield and Fiber Variability

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Abstract

Cotton (*Gossypium hirsutum* L.) fiber quality varies at the plant and field level. Mapping fiber quality within-plant and within-field provides data that can be used to assess the degree of variability. Field variability maps can be used to identify zones or bands within a field that can be segregated during harvest in order to minimize the number of bales with qualities outside the acceptable range. Plant maps revealed that no boll location consistently had low micronaire/micronafis values. Trends in micronaire/micronafis values and yield were similar for some field sites over a two-year period. Geostatistical analysis indicated that micronafis values from one transect exhibited significant spatial correlation in 1998. In 1999, yield from both transects and micronafis values from one transect were spatially correlated.

Introduction

Cotton yield and fiber quality are altered by numerous factors (3). Climatic factors include rainfall and temperature extremes. Non-climate factors include soil properties and management practices. Fruiting location maps of cotton plants have been used to describe the variability of fiber quality within plants (1,10,12). The cotyledonary nodes are designated as Node Zero and mainstem nodes are defined as places on the mainstem where monopodial or sympodial branches arise. Monopodial branches do not directly bear fruit but can give rise to sympodial branches that produce fruit. The first position on a sympodial branch is designated as fruiting position one (FP1) (7). Successive fruiting positions on a branch are designated FP2 and FP3.

While few incentives are offered for stronger and longer fiber as well as fibers with good micronaire values, there are significant deductions in the price for substandard cotton. Micronaire is a composite measurement of fiber cross section (fineness) and fiber cell wall thickness (maturity). The acceptable micronaire range is 3.5 to 4.9 and any fiber outside that range is subject to a price penalty. Micronafis is a micronaire analogue fiber property calculated by the Zellweger Uster Advanced Fiber Information System (AFIS) (Zellweger Uster, Inc., Knoxville, TN) (2). Although yields vary from year to year, within-field variability can be considerable. Coefficients of variation (CVs) for yield have been reported to range from 20% to 52% (4,9). Significant correlations between and among years have led to the conclusion that in some fields the relative productivity at each sampling site remained constant (4). When yield was ranked by quartile, approximately 40% of the sampling sites remained in the same quartile when two years were compared (4). Fiber properties vary within fields. In Texas, average fiber micronaire ranged from 4.6 to 5.1 with CVs ranging from 4.5% to 10.4% (4). Micronafis CVs over a two-year period ranged from 10.2 to 13.2% in South Carolina (9). It has been suggested that maximizing quality could be achieved by zoned or selective harvest (9).

The objective was to determine within-plant fiber quality variability and across-field variability and to identify factors contributing to high micronaire/micronafis values. The construction of field site fiber quality maps would allow for the optimization of harvest practices. For example, consistent trends in fiber properties for specific field sites over several years would serve as a template for zoned harvest. Zoned harvest would be conducted in a manner to minimize the number of bales with micronaire values above 5.0.

Experiments

The study was conducted in a 16.3 acre producer's field near Crowville, LA. Sampling sites were located on two east-west transects that ran perpendicular to the cotton rows and proceeded down a slight incline. This direction was selected so that the transects would traverse the area of the field that was expected to exhibit the greatest degree of variability in soil fertility and moisture properties. The soil at this site was mapped as a Loring silt loam (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs). Cotton (Deltapine 33B) was planted on 8 May in 1998 and 22 May in 1999 and harvested on 26 September in 1998 and 7 October in 1999. The location of the first sampling site was at the east end of Transect 1 near the top of the incline. Three hundred seventy feet to the north of Transect 1, at a similar elevation, was the first sampling point on Transect 2. Each transect had 12 sampling points spaced 75 ft apart (23 rows). The same locations in each transect were sampled in both 1998 and 1999.

Plants were collected in 3-ft lengths of row with the row centered on the transect marker. Bolls were mapped by branch (node) and position on the branch. Bolls that were missing seedcotton from one or more carpels were excluded. Small bolls (seedcotton weight less than 1 g) were not included. These small bolls would not be harvested by spindle pickers. Seedcotton was ginned on a laboratory roller gin where each boll was ginned separately. In 1999, one half of the fiber from each boll was used for fiber analysis and the other half was pooled and blended with fiber from the same transect site to create a blended sample. Fiber samples from individual bolls were analyzed using AFIS (2). Data analysis was performed using the SAS Means procedure for individual site analysis and SAS GLM procedure for fruiting position analysis. Yield data were also analyzed for spatial trends using GS+ (Gamma Design Software, Plainwell, MI, 1998).

Results

Seedcotton yield varied across the field. In 1999, more sites had yields below 1000 lb/acre than in 1998 (Table 1). The mean AFIS fiber maturity values from individual bolls within a transect site was calculated. Across Transects 1 and 2 in 1998, micronafis values ranged from 4.17 to 5.55 (Table 2). The standard deviations were large and indicated a high degree of variability among bolls within a transect site. Variability within a site was lower in 1999 and the range was from 4.87 to 5.66 across transects and sites (Table 2). When fiber was blended from individual bolls (1999) and then analyzed, micronafis values for most transect sites were similar to the mean value for individual bolls. Blended fiber samples may hide the degree of variability found at a transect site. Lewis (12) reported that an analysis of micronaire by boll position revealed a standard deviation level about four times higher than was expected in a bale of cotton. Both low and high yield sites (Transect 1 Sites 2 and 5) were associated with similar micronafis values (Table 1 and 2). In Texas, the relationship between yield and micronaire suggested that, as boll number per plant increased, micronaire values decreased (4).

Table 1. Seedcotton yield across transects on 1998 and 1999.

Transect	Site	**Yield** (lb/acre)	
		1998	**1999**
1	1	1081	863
1	2	1816	1346
1	3	1124	985
1	4	894	1027
1	5	811	755
1	6	999	1024
1	7	1302	813
1	8	849	1063
1	9	1002	1083
1	10	1453	1106
1	11	1017	626
1	12	969	1108
2	1	1189	975
2	2	843	716
2	3	424	473
2	4	1074	1316
2	5	1136	968
2	6	1412	1335
2	7	1343	1139
2	8	1717	939
2	9	1489	1136
2	10	1189	1496
2	11	1350	642
2	12	1686	473

Table 2. Micronafis values across transects in 1998 and 1999.

Transect	Site	1998, n	1998 Mean micronafis individual bolls	1999, n	1999 Mean micronafis individual bolls	1999 Mean micronafis blended fiber
1	1	39	4.17±0.94	35	4.87±0.61	4.71±0.21
1	2	57	4.34±0.79	47	4.95±0.74	4.29±0.11
1	3	42	4.43±0.99	32	5.64±0.78	5.66±0.14
1	4	33	4.64±0.82	34	5.23±0.44	5.19±0.16
1	5	30	4.33±1.44	29	4.82±0.76	4.67±0.09
1	6	36	5.27±1.17	36	5.09±0.76	4.93±0.23
1	7	46	4.83±1.07	29	5.14±0.60	4.95±0.15
1	8	31	5.04±1.12	38	5.29±0.81	5.22±0.17
1	9	38	5.55±0.94	39	5.56±0.70	5.52±0.06
1	10	48	4.94±0.95	36	5.10±0.44	4.92±0.02
1	11	36	4.42±0.85	25	5.54±0.56	5.53±0.12
1	12	27	5.37±0.85	38	5.40±0.91	5.08±0.09
2	1	41	4.65±0.73	38	4.97±0.50	4.80±0.11
2	2	29	4.60±0.90	29	4.58±0.56	4.52±0.11
2	3	16	5.04±0.87	18	5.07±0.49	4.99±0.16
2	4	37	4.81±1.01	45	4.92±0.59	4.88±0.11
2	5	42	4.83±0.94	34	5.07±0.54	5.11±0.14
2	6	50	4.59±1.08	45	4.93±0.90	5.06±0.10
2	7	47	4.93±0.87	40	5.40±0.65	5.75±0.04
2	8	57	5.19±0.94	35	5.37±0.71	5.37±0.12
2	9	45	4.67±1.07	41	5.00±0.77	5.39±0.09
2	10	42	5.02±1.05	45	5.30±0.88	5.17±0.11
2	11	47	4.46±0.77	23	5.66±0.69	5.78±0.17
2	12	52	4.98±1.16	19	5.24±0.89	5.51±0.16

Several interesting trends become apparent if yields and micronafis values from each transect position are ranked in decreasing order. In both years, the highest yields were obtained from Site 2 in Transect 1 (Table 1). Similarly, some of the lowest yields were obtained from Site 5 in Transect 1. In Transect 2 the patterns are not as evident, although the lowest yields for both 1998 and 1999 were observed at Site 3. If the micronafis data are examined a stronger pattern is seen. Although the order is not exact, the same sites tended to group in areas of high and low micronafis for both 1998 and 1999. Consider the micronafis values for Sites 9, 12, 8 (high) and 2, 5, 1 (low) for Transect 1 (Table 2). Alternatively consider values for Sites 10, 12, 8, 7 (high) and 1,2,6 (low) for Transect 2. These patterns indicated that a spatial trend may be present in the yield and micronafis data from this study. A geostatistical analysis was performed to evaluate this possibility.

Variogram analysis was performed on both yield and micronafis data from each transect to determine if spatial trends were present (Table 3). The variogram measures the average dissimilarity between data points separated by a given distance (5). The graphical variogram provides a summary of measured spatial structure of a given property within the experimental location. The experimental variogram, which is computed from the data, is usually described or fit to a theoretical variogram model (11). Important features of the variogram include the range, sill, and nugget. The *range* is the maximum distance at which spatial correlation is observed. This is the distance at which the variogram plot exhibits a plateau. The *sill* is the value that corresponds to the range distance (or plateau). The variogram exhibits a *nugget effect* if a discontinuity (from zero) is present at the origin (6).

Table 3. Variogram analysis for transects in 1998 and 1999.

Year		Transect	Model	Range	r^2
1998	Yield	1	ns[a]	-	
		2	ns	-	
	Micronafis	1	L	na[b]	0.64
		2	ns	-	
1999	Yield	1	S	631	0.91
		2	L	na	0.41
	Micronafis	1	ns	-	
		2	L	na	0.59

[a] Variogram analysis did not result in a significant spatial correlation. (ns = not significant).

[b] Values for the variogram range are arbitrary with the linear model and are therefore not included. (na = not aplicable).

Similar trends were observed between the individual boll means and the blended fiber from 1999, so only the individual boll values are included in this discussion. In the 1998 harvest season only the micronafis data from Transect 1 exhibited spatial correlation (Table 3). It was not possible to determine the range of spatial correlation, due to the fact that a linear variogram best described the data. The linear variogram, by definition, does not obtain a sill and thus does not have a range of spatial correlation (6). An estimated range is calculated by GS+, however this value is arbitrary and is thus not included in this discussion. In 1999, the yield data from both transects and the micronafis at Transect 2 all exhibited spatial correlation (Table 3). The yield data from Transect 1 were described by a spherical variogram and possessed a range of spatial correlation of 631 ft. The yield data from Transect 2 were described by a linear variogram. Finally, the micronafis data from Transect 2 were also described by a linear variogram. The presence of some spatial variability in this experiment is not surprising considering the difference in elevation and topography present in the field. Differences in yield and micronafis may also be related to variability in soil properties, which would also be influenced by topography. The greater degree of spatial correlation observed in 1999 may be related to increased stress conditions that also resulted in decreased yields. The results also indicate that mapping of fiber yield and quality though geostatistical methods may help steer efforts in zonal harvest when combined with soil maps. This possibility will be examined in a later manuscript.

Within a transect site, plant maps were constructed and bolls were categorized by branch (node) and position on a branch. After fiber analysis, mean micronafis values were obtained for fiber from bolls at FP1 Nodes 5 to 8, FP1 Nodes 9 to 12, FP1 Node 13 and above, FP2 all nodes, FP3 and above all nodes, and all monopodial branches. Micronafis values at different positions and node locations were similar (Table 4). Micronafis variability was greater in 1998 than in 1999. It has been reported that variation in micronaire depended on position and node location in Arkansas (12). Lewis found that bolls at FP2, FP3 and above, and bolls on monopodial branches had lower micronaire values than FP1 bolls (12). The lower micronaire bolls contributed to lower micronaire of the blended sample (12). In both 1998 and 1999, FP2, FP3 and bolls from monopodial branches would not be expected to lower blended micronafis samples. When fiber is shortened, micronaire often increases (13). Shortened fiber was eliminated as a contributor to high micronafis value in 1999 since fiber length did not decrease in bolls from FP2, FP3, or monopodial locations (*data not shown*). In both years reduced boll load may have contributed to high micronafis values. Mean number of bolls per plant per transect site ranged from

2 to 6. With a reduced boll load the supply of carbohydrate is greater than the demand. The excess carbohydrate contributes to increased fiber cell wall thickness and increased micronaire values (3). In 1998 soil properties for this field were related to fiber properties (8). The best predictor of fiber micronafis and other maturity measurements was identified as soil Mg followed by K, Cu, and As (8).

Table 4. Micronafis variability across transect sites at different boll position and node locations.

Year	Position and node	Sites mean	Standard deviation	Coefficient of variation	Maximum	Minimum
1998	FP1, 5-8	4.75	0.87	18.4	6.37	3.92
	FP1, 9-12	4.75	0.87	18.4	5.60	4.16
	FP1, 13>	4.81	1.16	24.2	5.97	3.14
	FP2	4.70	1.00	21.2	5.90	3.99
	FP3	4.93	1.21	24.5	5.99	3.95
	mon[a]	4.92	1.00	20.4	5.91	2.86
1999	FP1, 5-8	5.17	0.57	11.0	5.81	4.03
	FP1, 9-12	5.06	0.72	14.2	5.73	4.20
	FP1, 13>	4.93	0.71	14.4	6.47	4.18
	FP2	5.12	0.76	14.8	6.22	4.52
	FP3	5.24	0.60	11.4	6.08	4.10
	mon[a]	5.44	0.73	13.5	6.28	4.82

[a] Monopodial locations.

Factors contributing to differences in fiber micronafis include soil properties, topography, and to some extent boll numbers per transect site. Dramatic differences in yield between Transect 1 Site 11 and Transect 2 Sites 11 and 12 in 1998 and 1999 were accompanied by changes in micronafis values. Further research in geostatistical mapping of fiber yield and quality could result in a zonal harvest strategy that maximizes fiber quality within each bale.

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